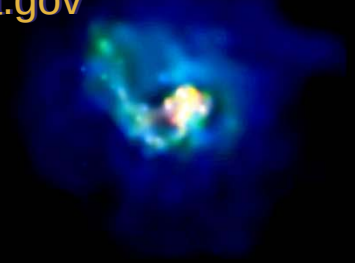
Single Launch Configuration

Constellation-X

The Constellation X-ray Mission



Mission Configuration

Gabe Karpati, Mission SE
gabriel.karpati@nasa.gov
301-286-4468

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Outline

- **Mission Configuration**
  - Requirements
  - Launch / Orbit / Timeline
- **Observatory Configuration**
  - Subsystems Highlights
  - Resource Budgets

Introduction

Charge

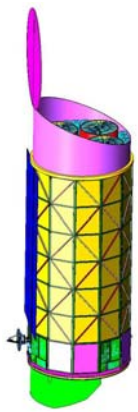
Refine 10/4 Observatory design to a near Phase-A maturity

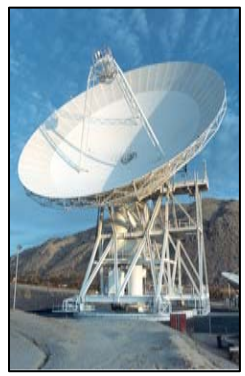
Con-X 10/4 Engineering Team (GSFC except where noted)

Systems:	Gabe Karpati, Tom Buckler (Swales), Jamie Britt, Mark Freeman (SAO)
Instrument Systems:	Gary Sneiderman
Flight Dynamics:	Michael Mesarch
ACS:	Dave Olney
Mechanical:	Jeff Stewart, Bobby Nanan
Propulsion:	Rick Caverly (OSC), Morris Frayman (Swales)
Thermal:	Miles Newman (Swales)
Power:	Bob Beaman
RF Comm:	Ron Vento
C&DH:	Terry Smith
Flight SW:	Carver Audain
Disposal:	Scott Hull

Constellation-X Mission Elements

- Constellation-X Mission
  - Launch Segment
    - Launch Vehicle
    - Payload Adapter
    - Launch Site Services
  - Observatory Segment
    - Optics Module
    - Metering Structure Module
    - Focal Plane Module
    - Spacecraft Subsystems
  - Ground Segment
    - Ground Stations
    - Mission Operations Center
    - Science Operations Center



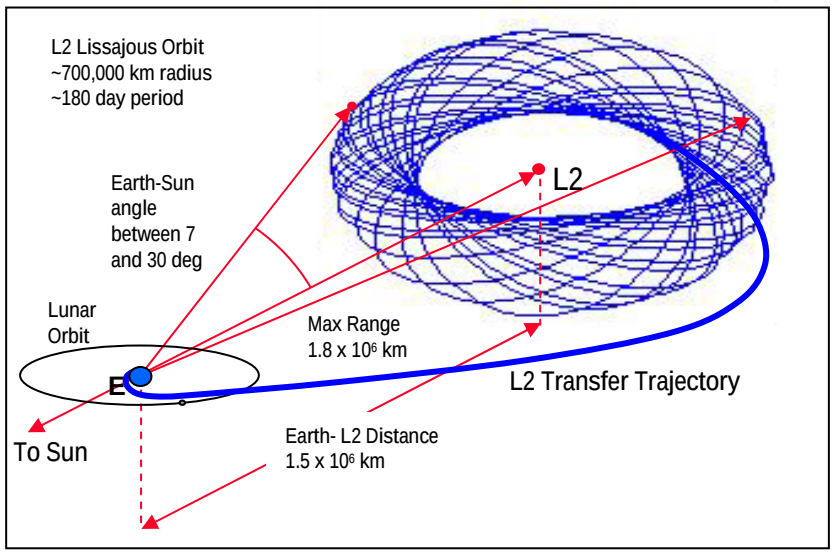


Performance Requirements

- **Sizing**
  - Mission Life 5 years, 10 years goal
  - Size consumables for 10 years / 115 m/s total delta-v
  - Size Structure and Propulsion Tanks for max liftoff mass, others for CBE
  - No performance degradation w/ single point failure
- **Environment**
  - Design for 50 kRad TID
  - Micrometeoroid protection required
- **Timing accuracy**
  - ±100 μsec to UTC

Launch

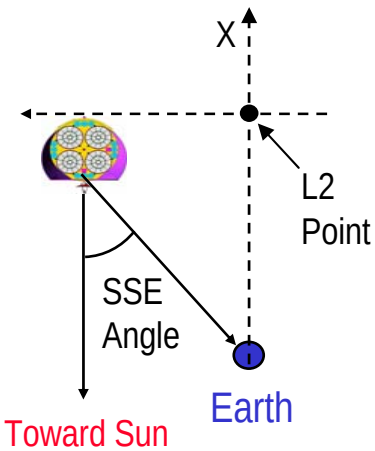
- **Launch Vehicle: Delta IV- Heavy**
  - 2-stage, all liquid, relatively low dispersions
  - Most capable US LV, throw mass: 9380 kg to L2 (C3 = -0.5)
  - Fairing internal diameter: 4.5 m
- **4394-5 Payload Adapter ("Elephant Stand")** 
  - Allows for no CG height limitation
  - 386 kg PAF weight factored in published throw mass
- **Direct insertion to L2**
  - Several launch opportunities available almost every day of the year
    - Except 3-4 days when Moon is "in the way"
  - Launch energy: -0.5 km2/s2
  - No lunar phasing loops



Courtesy Mark Beckman, Mike Menzel - JWST

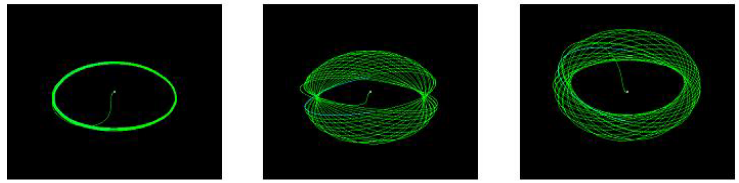
Orbit

- **100 days cruise to L2**
  - **Outgassing, then checkout during entire cruise**
- **Orbit: L2; Large Lissajous orbit (~700,000 km)**
  - **Smallest orbit with zero m/s insertion delta-v**
  - **Orbit mostly inside Earth's Magnetosheath**
  - **No Earth shadows during length of mission at L2, potential of lunar penumbra < 14% obscuration**
  - **L2-Earth-SC Angle varies from 7° to 30° over 10 years**



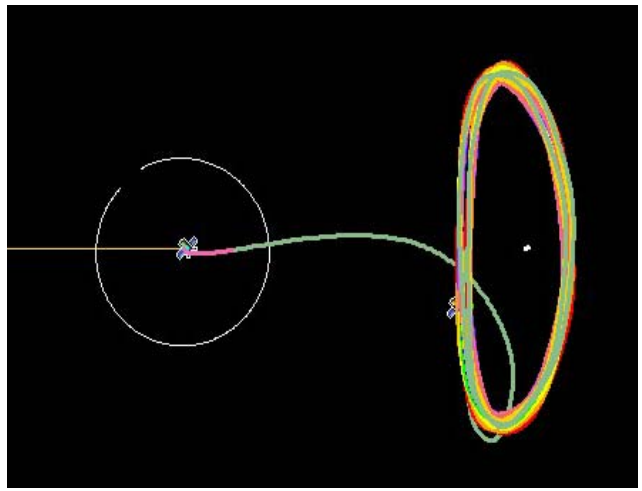
  - **30 min / day undisturbed ranging required for 21 days before every stationkeeping burn**

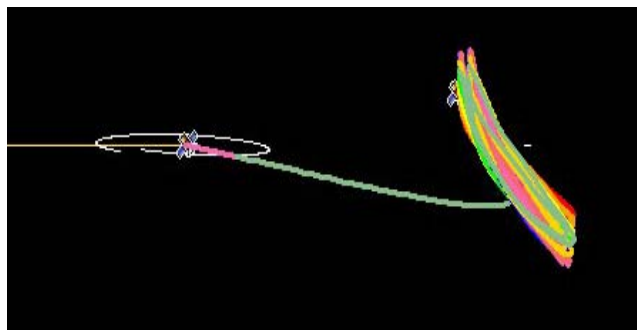
halo Lissajous torus



Orbit varies between these above as a function of launch time, even within the same day!

Courtesy Mark Beckman, JWST





Nominal Mission Timeline

- **Launch (L)**
  - Instruments and Cryo completely deenergized, S/C mostly unpowered
  - LV First stage is ballistic (falls into ocean)
- **Transfer Trajectory Insertion (TTI): L + 25 to 120 minutes**
  - Need live RF Comm w/ ground
- **LV Separation: TTI + 5 minutes**
  - LV 2nd stage remains on trajectory to near-L2 cruise, behind ConX
  - Turn S/C on, acquire nominal attitude, begin S/C Checkout; Some Instruments on, Cryo off
- **ELV Dispersion Corrections: TTI + 12 to 24 hours**
- **First and Second Mid-Course Correction: TTI + 15 days, + 60 days**
- **Open telescope covers, outgas Observatory**
- **Conduct checkouts and calibrations throughout cruise**
- **L2 Orbit Insertion (L2 OI): ~ TTI + 100 days**
- **Science Ops start at L+100 days**
  - L2 Stationkeeping burns: Every 21 - 90 days
  - L2 Momentum Unloading Burns: Every 1-3 days w/ thrusters in pure couple for forceless torque
- **EOM Disposal: L + 10 years ++**
  - Delta-v << 1 m/s to driftaway trajectory, then passivate Observatory

Observatory Configuration

Optics Module (OM)

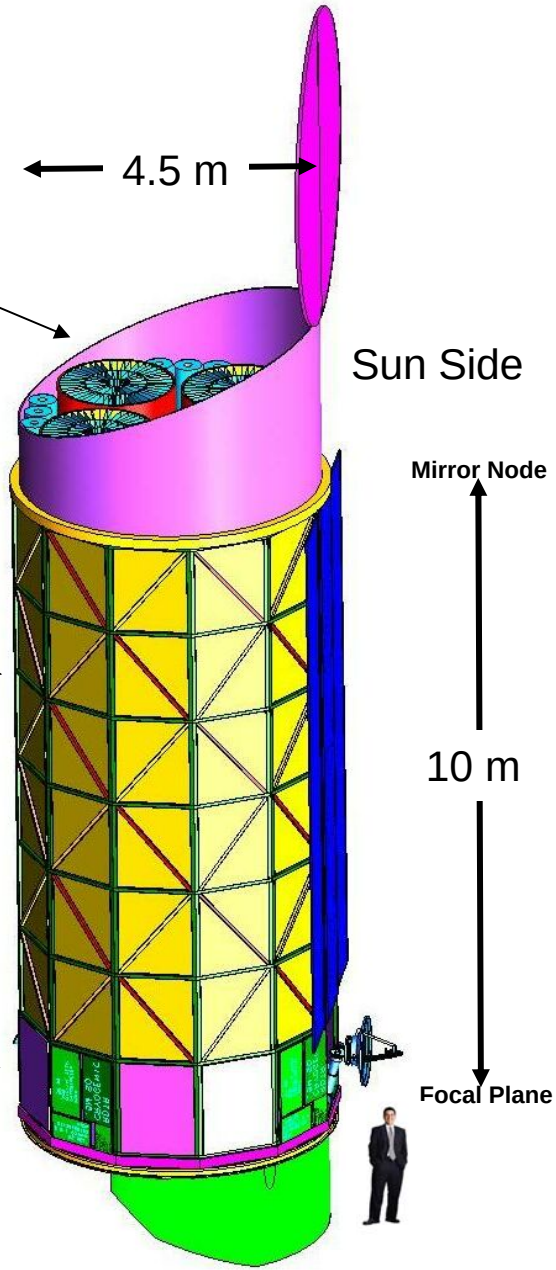
- SXT and HXT mirror assemblies
- FMA Thermal System and control electronics
- Door/sunshade and internal cover/door
- Star Tracker

Metering Structure Module (MSM)

- Fixed metering structure
- Light and Micrometeoroid shield
- Internal Baffles
- Solar Arrays

Focal Plane Module (FPM) and S/C Bus

- All instrument detector systems on aft-most deck, baffles
- Propulsion Tanks
- Electronics for instruments on panels and Benches
- Spacecraft bus subsystem components on panels and deck



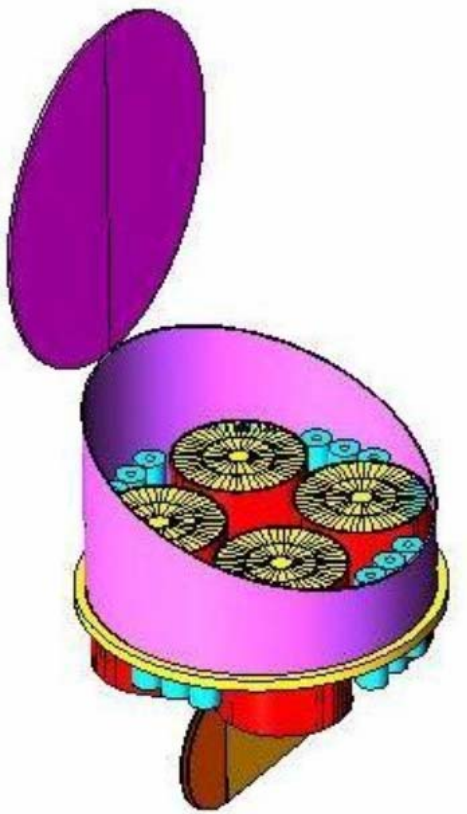
Con-X Modules Definition

Observatory

Observatory = Optics Module (OM) + Metering Structure Module (MSM) + Focal Plane Module (FPM) + Spacecraft Subsystems (SCS)

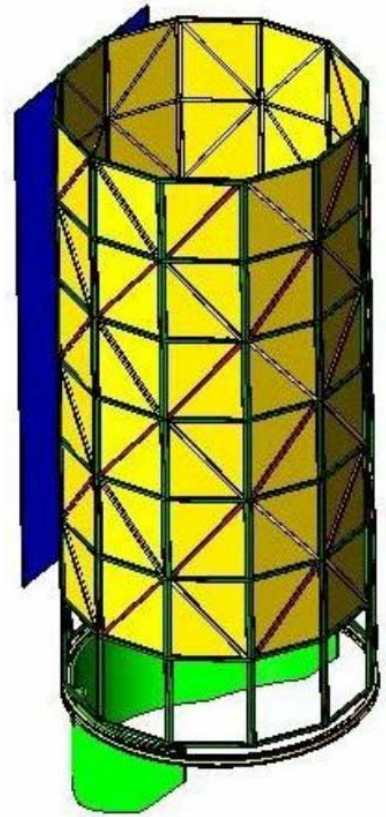
==========

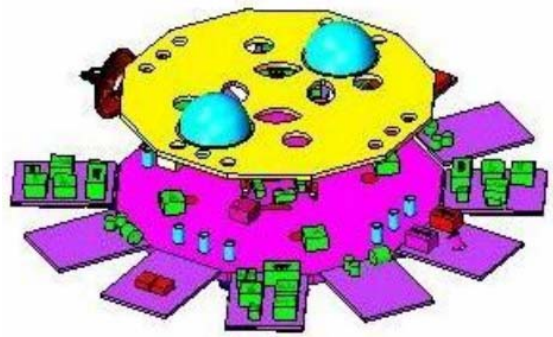
- **The Optics Module (OM) comprises:**
  - 4 SXT Flight Mirror Assemblies (FMAs)
    - SXT Mirrors
    - Complete set of RGAs
    - Pre and Post-Collimators with thermal control hardware
    - FMA Structure
  - 12 HXT Mirrors
  - Fore and Aft Telescope Doors
  - Star Tracker



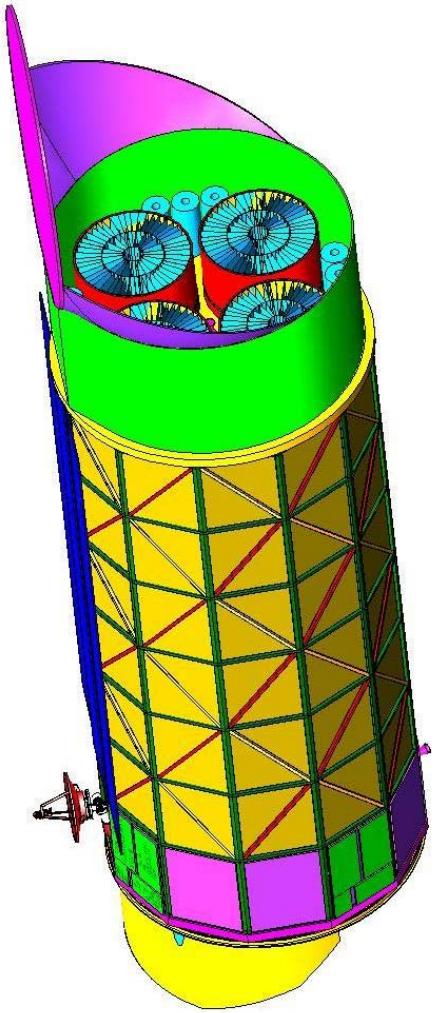
Con-X Modules Definition, cont'd

- **The Metering Structure Module (MSM) comprises:**
  - Structure
  - 1 mm thick composite Thermal/Light /Micrometeorite Shroud, also acting as shear panels
  - Solar Array Assembly
  - Two partially Tantalum shielded Internal Baffles
- **The Focal Plane Module (FPM) comprises:**
  - Instrument Bench including:
    - Some Instrument Electronics Boxes
    - Propellant Tanks
  - Detector Bench, including:
    - 4 XMS Detectors with Cryo-coolers, associated Focus Mechanisms and Aft Radiators
    - 12 HXT Detectors
    - 4 RGSs (including RFCs and ZOC's (TBD))
    - Some Front End Instrument Electronics Boxes
  - Aft Sunshield
- **Spacecraft Subsystems (SCS):**
  - Most s/c components are mounted on FPM panels and benches
  - Numerous parts require off-FPM placement, such as Star Trackers, Thrusters, etc.

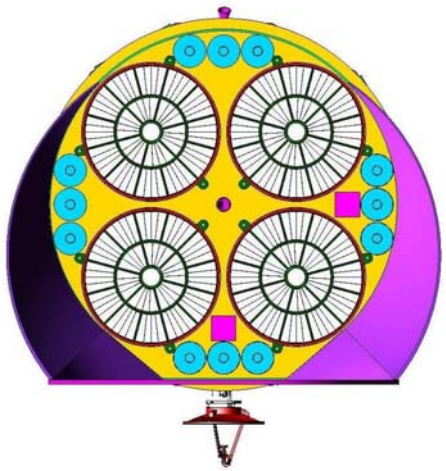


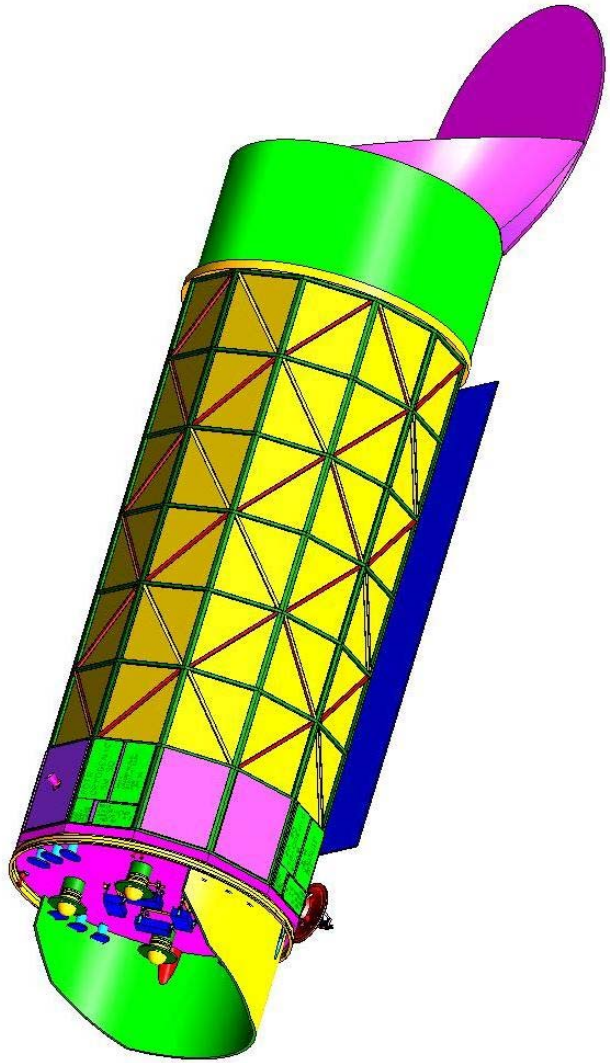


Observatory - Front and Aft Views

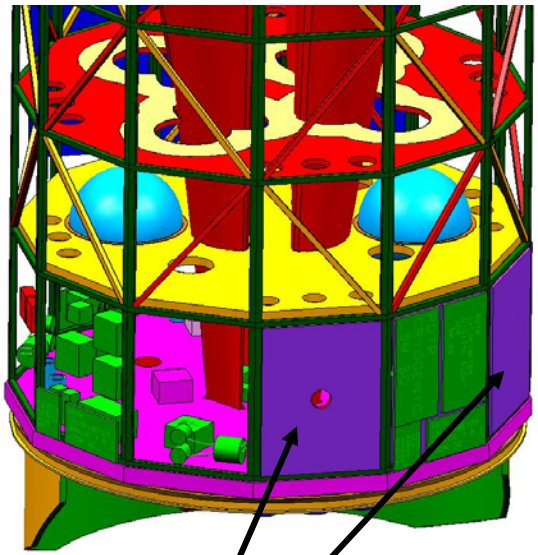


Front View





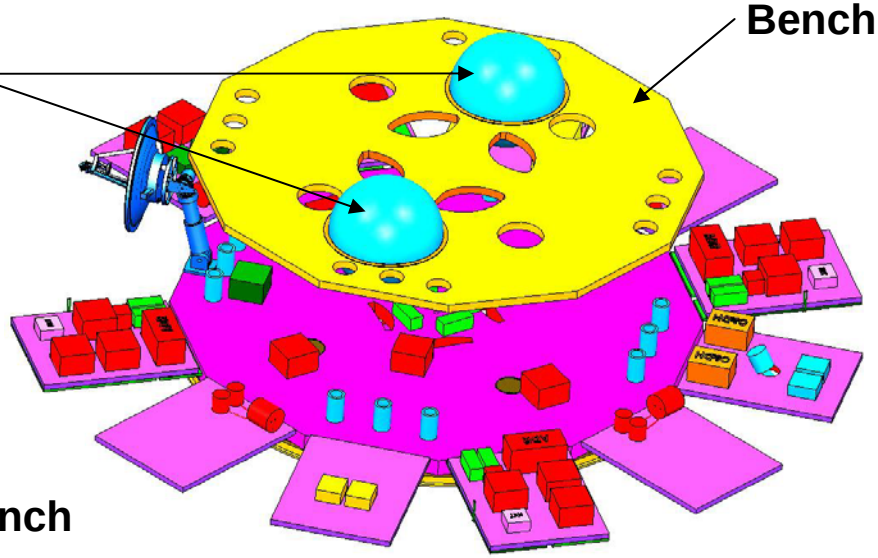
FPM and SCS - Detailed Views



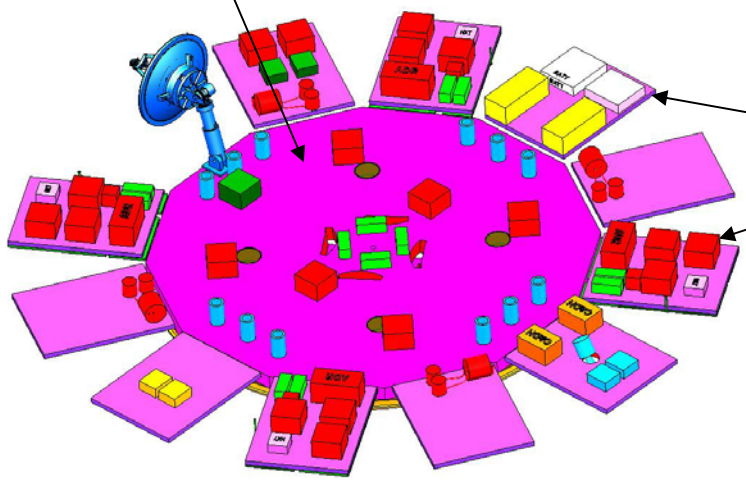
Radiators

Propellant Tanks

Instrument Bench



Detector Bench
(Front Side)



Side Panels
with most
SCS Components

Subsystems Highlights

- **ACS**
  - Pointing knowledge: ~3 arcsec (3σ), pointing control: ~30 arcsec (3σ)
  - Slew: 2 degrees per minute
  - Five Reaction Wheels, Honeywell HR 150: 203 Nms, 1.62 Nm
  - 2 ea. 3 arcsec (3σ) Star Trackers (CT 602) slightly canted, Sun Sensors, 10 year IRUs
  - ACE and S/W embedded in C&DH
  - Momentum unload every day w/ pure couple thrusters w/ minimum trajectory disturbance
- **Mechanical**
  - 12 sided composite Structure with Al honeycomb decks and side equipment panels

  <u>Deployables:</u>
  - Solar Array Panels (some body-mounted, some deployed with two hinge-lines)
  - 2 axis actuated High Gain Antenna, 1 m dia. On 1.5 m long boom
  - Telescope Fore Cover, and Telescope Aft Contamination Cover
  - Detector Contamination Covers (TBD)
  - FPM Sunshade (TBD)

Subsystems Highlights

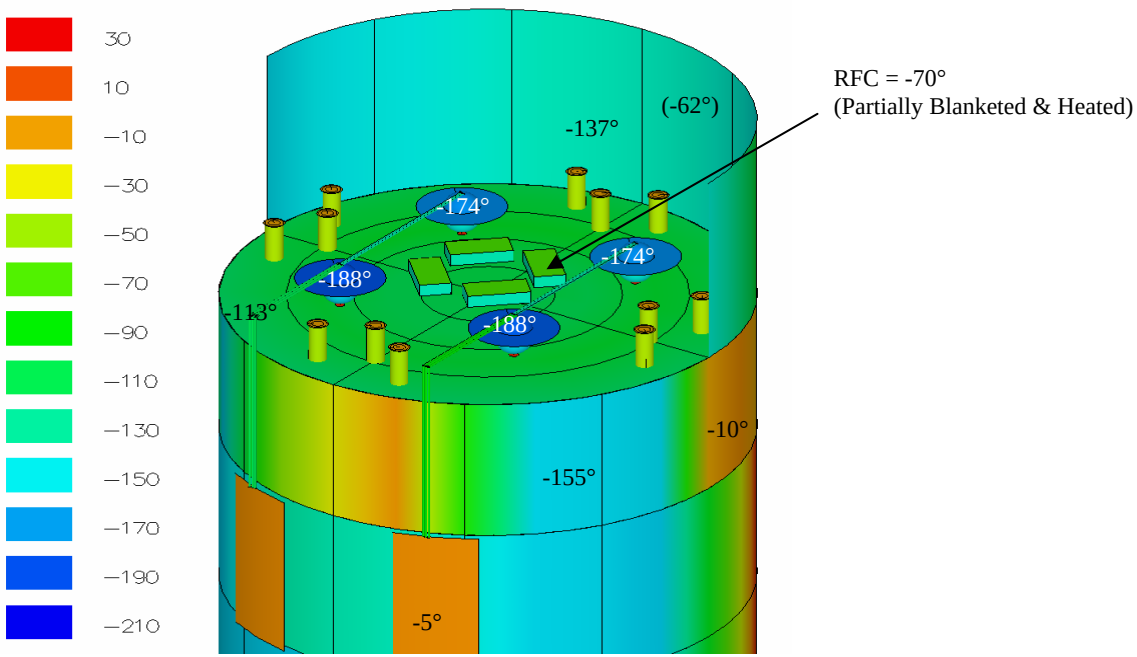
- **Propulsion**
  - Hydrazine bipropellant (N2O4/N2H4) to minimize propellant and prevent hydrocarbon contaminates
  - Two modified RCA S5000 propellant tanks, 21”, sized for 10 years / max mass, one pressurant tank from PSI Inc.
  - Propellant load of 345.5 kg sized for a 7000 kg S/C dry mass
  - 12 (TBD) ea. AMPAC (N2O4/N2H4) 5 lbf (Pt/Rh) thrusters
- **Power**
  - 4900 W total Observatory load
  - Bus is battery dominated
  - MAP like PSE
  - ~36 m2 S/A on seven panels (four deployed)
  - 3 ea. 40 Ah Lithium Ion Battery, < 50% DoD

Delta-V budget

Launch Window	10 m/s
ELV Dispersion Correction	40 m/s
Mid-Course Corrections (2)	10 m/s
L2 Stationkeeping (10 yrs)	40 m/s
Margin (15%)	15 m/s
Total	115 m/s

Subsystems Highlights

- **Thermal**
  - All requirements met (per ~100 node thermal model analysis)
  - FMA: Electrically heated Pre- and Post-Collimators maintain mirrors at 20ºC at all times
  - MSM: Conventional design w/ radiators; circumferential gradient 8 ºC
  - FPM: Embedded heat pipes to lower gradients
  - Cryocoolers: Sunshade and passive radiators maintain < 150 ºK
  - Cold Head: Heat pipes carry heat load to radiators



Subsystems Highlights

- **RF Comm**
  - Ka band 1 m dia. 2 axis actuated High Gain Antenna, 40 Mbps telemetry to DSN 34 m antenna
  - S band Omni antennas, 2 kbps command/telemetry and ranging to DSN 34 m antenna
  - 15 min data-contact every other day, 30 min ranging every day (or possibly 1 hr every other day)
  - > 3dB link margin (where required)
- **C&DH**
  - Two separate (redundant) C&DH units
  - RAD 750 Single Board Computer w/ PowerPC 603/750 microprocessor
  - Science payload connections: RS-422
  - Instrument Suite Total data rate 192 kbps avg. / 2560 kbps peak
  - One 40-Gbit embedded bulk memory card per side
  - Oven controlled Ultra Stable Oscillator, accurate to 1.59 microsec/hour = 38 microsec/day

Mass Budget

- **Mass Growth Margin relative to Current Best Estimate (CBE): 29%**

	CBE	Alloc.
Optics	**2870**	**3595**
SXT/FMA	2303	2801
FMA Structure	1152	1498
RGA	360	504
HXT Optics	207	290
Instruments	**928**	**1296**
XMS	588	823
RFC	132	182
HXT	208	291
Observatory Subsystems	**2950**	**3760**
ACS	164	180
Structure	1682	2170
Mechanisms	322	404
Propulsion	54	70
Thermal	309	402
Power	165	204
Harness	189	246
Communications	46	57
C&DH	21	27
Sep. System and Misc	**200**	**260**
OBS. DRY MASS	**6949**	**8911**
Propellant	346	451
OBS. WET MASS	**7294**	**9362**
LV Throw Mass	9380	9380
Margin	2086	

Overall Systems Assessment

- **The 10/4 configuration meets requirements**
  - **All s/c bus and subsystems requirements well understood, and met w/ baseline design**
- **The 10/4 configuration is conventional***
  - **Most s/c components are "off the shelf"**
  - **Conventional Ground Segment (DSN)**
  - **Conventional Mission Operations**
  - **The 10/4 Observatory employs no new technologies***
- **Everything accounted for**
  - **All components identified, placed on the 10/4 Observatory, and accounted for in the design, mass, and power budgets**
- **Observatory composite mass margin is 29%**
  - **Right at the ceiling of the "OK" range**
  - **In the process of scrubbing some heavy subsystems; need better definition for more accurate mass estimate**

*** Aapart from technologies associated with the Flight Mirror Assembly and the Instruments**